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TEMPERATURE RISE ON CLEAR MORNINGS

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Summary.—Gold's method for estimating maximum temperatures has been extended empirically to draw a forecast curve of the rise of temperature to the maximum on clear days. To do this, four points are fixed which correspond to the provision of four given amounts of energy by insolation to the lowest layers of air. Monthly average values are evaluated of the times taken from sunrise for these given amounts of energy to be absorbed. These figures, which show a low probable error, are used to make actual forecasts.

Introduction.—It has been shown by Gold* that the maximum day temperature at screen level may be estimated on occasions of unobstructed solar radiation by drawing a dry-adiabatic line on the tephigram in such a position that the area between the line and the early morning ascent curve represents a certain amount of energy dependent on the season of the year. Gold arrives at his figures by theoretical arguments which admittedly are not rigorous; the energy absorbed by the ground itself is ignored, and the departure of the ascent curve at the time of maximum temperature from the dry adiabatic is often quite pronounced. Nevertheless, the argument leads to results which are useful in practical forecasting and are therefore justified empirically whatever the theoretical shortcomings may be.

There are therefore good grounds for extending the work empirically with the hopes of arriving at a forecast curve of the diurnal rise of temperature with time after sunrise.

Diurnal temperature curves.—In the practical drawing of such a curve we can plot two points. The first of these is the sunrise temperature (actual or forecast according to when the forecast is being made). Then using the latest upper air information and the monthly figures given by Gold we are able, with suitable adaptation of the lowest part of the temperature-pressure curve on the tephigram, to plot the maximum temperature to be reached.

It now remains to draw the correct curve of the rise of temperature with time between sunrise and the time of maximum temperature. The approximate

*GOLD, E.; Maximum day temperatures and the tephigram. *Prof. Notes met. Off., London*, **5**, No. 63, 1933.

shape of this curve is shown in Fig. 1. It has a sharp rise of temperature from the minimum value just after sunrise, after which the curve flattens and reaches a maximum about $2\frac{1}{4}$ hours after noon and then falls towards sunset.

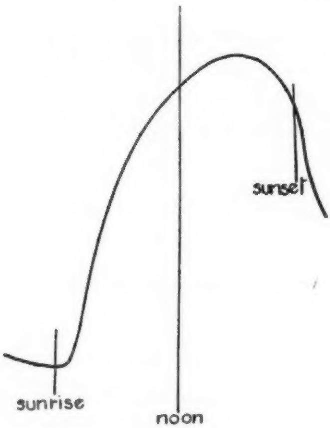

FIG. 1

To fill in this part of the curve more accurately than can be done by simple interpolation an attempt has been made in this paper to fix some points on this part of the curve for each occasion.

It has been found convenient in this paper to confine attention to one station, Northolt, to eliminate as far as possible variations of diurnal temperature range due to different surface and soil characteristics. The normal ascent curve at sunrise after a clear radiation night shows an inversion in the lowest layers. In Fig. 2 the ascent at sunrise is shown by an inversion ACB. If an isothermal

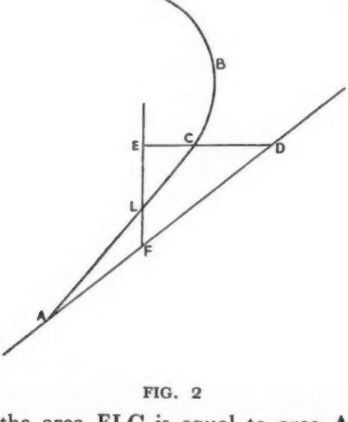

FIG. 2

FE is drawn so that the area ELC is equal to area ALF where area FED represents the amount of energy to be added up to the time of maximum temperature then DCB will represent the temperature-height curve at the time

of maximum temperature. The actual rise of surface air temperature will be from A to D. Since the rise FD is fixed for any position on the line EF the actual rise from A to D will vary with the shape and slope of the line ACB. Thus a very steep inversion will produce a relatively large rise and a slight inversion or lapse will produce a smaller one. Thus the shape of the forecast curve to be drawn will depend directly on the profile of the ascent curve at sunrise and during the period of heating. The screen temperature reached at any given time after sunrise depends on the ascent curve. The amount of energy added to the lowest layers of air in the same time after sunrise is, however, independent of the ascent curve, and it is assumed that it will vary only with the season of the year as with Gold's figures for maximum temperature.

Monthly values of time taken to add given amounts of energy.—A period of 2 years was selected for which Northolt hourly observations were readily available—January 1945 to December 1946.

Days which fulfilled the following conditions were selected :—

(1) Low cloud amount less than 7 tenths between sunrise and noon or only increases above this value for one hourly observation.

(2) No medium or high cloud or not more than 3 tenths for more than one hour.

(3) No rain reported during the previous 12 hours.

(4) Visibility not falling below 1,000 yd. for more than 3 hours and no thick fog at any time.

Although it would be ideal to use only completely fine days, such days were not sufficiently numerous to allow satisfactory computations to be made in the period chosen. Conditions (1) and (2) ensure that interference with solar radiation by cloud is kept at a minimum and that the days selected are mainly clear of cloud or of the type with only broken cumulus. Condition (3) eliminates days on which the diurnal range of surface temperature is badly affected by wet ground, as would be the case on a clear morning in a ridge of high pressure immediately behind a cold front which has passed during the latter part of the night. It was not possible to take greater account of the effect of surface moisture in using heat for evaporation. This does appear to affect the results in the case of one month, June, as shown later. Condition (4) is mainly designed to eliminate days on which solar radiation is reduced over a period of some hours by thick fog. Attempt has been made as far as possible to eliminate days of this type but to include days which would otherwise be suitable but which have a certain amount of early morning ground fog only. An important aid in deciding which days to include here has been whether the sky has been reported visible or obscured during the period.

An examination of the upper air data available for the morning of each occasion was next made. Since there is no upper temperature sounding in the immediate vicinity of Northolt, the choice of suitable days usually lay between Larkhill and Downham Market. The wind was first examined from the surface up to 900 mb. The prevailing direction shown was usually sufficient for a choice to be made between the two as a basis for drawing on the tephigram an estimated ascent over Northolt. With some wind directions such as 220–270° and 360–40° this presented little difficulty but with others considerably more care was necessary. With winds between W. and N. fine mornings ful-

filling the above requirements were of frequent occurrence, and a comparison of both Larkhill and Downham Market temperatures up to 900 mb. was necessary with occasional reference to Liverpool. It was necessary to reject some otherwise suitable days when temperatures showed considerable differences between the two.

Similar difficulties arose frequently on days with E.–SE. winds. Neither Larkhill nor Downham Market could be taken as representative of Northolt as the air at all three places had recently come over sea tracks differing both in length and temperature. On this account many days with winds from this direction had to be rejected.

The data used were basically the 0600 G.M.T. ascents, but reference to 1200 G.M.T. ascents occasionally showed considerable temperature changes above the level affected by surface heating, and a few days were rejected on this account also.

Nevertheless 59 days were found in the 2-year period which fulfilled all requirements.

The appropriate ascent for 0600 G.M.T. was first plotted on the tephigram up to 900 mb., and the lowest hourly temperature for Northolt was also plotted as an additional surface reading, no account being taken of the 300-ft. difference in level between Larkhill and Northolt. This implies in effect that air which had been over Larkhill has descended 10 mb. or so on reaching Northolt. While being only an approximation to the truth it will have little effect on the tephigram areas to be measured in the next stage. Downham Market and Northolt are almost at the same height so the problem does not arise in this case.

Assuming air above the lowest layers at Northolt is represented by the chosen ascent it is now possible to draw an estimated curve for Northolt which would represent the actual conditions at sunrise with reasonable accuracy.

Using this estimated ascent, the next step was to find for each day the temperature which would be reached when the energies corresponding to 0·25, 0·5, 1 and 2 cm.^{2} on the tephigram* have been supplied to the lowest layers.

Hourly temperature observations for each day show the time at which these temperatures were actually attained. These times were expressed in hours from sunrise. The temperature observations used were taken to the nearest degree and interpolations between hourly readings were made as required to the first decimal place of an hour. The times so derived were meaned for each month and are shown in Table I.

Discussion of results.—To obtain some idea of the value of these monthly average times for forecasting, the probable errors of the observed times in hours were evaluated. These are also shown in Table I. In order to obtain a sufficient number of observations for the evaluations, several of the months have been grouped together before computing the values of 0·6745 root mean square of the time measured minus the time forecast. The values so derived indicate the anticipated accuracy of the forecast. They show that in most cases there is at least an even chance of the time forecast being within approximately half-an-hour of the actual time, and in no case is the probable error greater than about 35–40 min.

*London, Meteorological Office. Tephigram Form 2810. Energy constant: $2{\cdot}78 \times 10^6$ ergs/cm.^{2}

TABLE I

Energy equivalent		Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
cm.^{2}	No. of days	6	8	12	1	4	4	3	1	5	3	3	4
0·25	Average (hr.)	2·2	2·17	1·86	1·5	1·77	1·4	1·3	2·0	1·9	3·0	3·1	2·75
	Probable error	0·33		0·25	..		0·28		..		0·18		
	No. of days	6	8	13	1	4	4	3	1	5	3	3	4
0·5	Average (hr.)	3·2	2·8	2·2	2·0	2·4	2·07	1·9	2·6	2·4	4·1	4·0	4·6
	Probable error	0·49		0·3	..		0·28		..		0·58		
	No. of days	6	8	13	..	4	4	3	1	5	1	2	2
1	Average (hr.)	4·3	3·45	2·9	..	3·07	2·77	2·86	3·8	3·3	3·7	4·6	4·7
	Probable error	0·44		0·12	..		0·33		..		0·42		
	No. of days	3	8	12	..	4	3	3	1	5	..	..	..
2	Average (hr.)	5·8	4·4	3·6	..	3·97	3·9	3·6	6·8	4·4	..	..	..
	Probable error	0·61		0·57	..		0·34		..		0·48		

In Fig. 3 the monthly values are plotted with time in hours from sunrise against time of year. Smoothed curves drawn through the points show the general form of a sine curve with a minimum value in June and a maximum in December as would be expected from the annual solar cycle and the variation of strength of insolation. In the case of energy corresponding to 2 cm.^{2} the curve runs off to infinite values during the months of November, December and January as the required temperature is never reached. This is borne out by Gold's monthly figures for the area up to the time of maximum temperature which are less than 2 cm.^{2} for these three months.

Individual monthly values are of interest. In particular the month of June shows a higher value than would be expected from the general run of the curves. Although only four occasions were found in June during the 2 years closer agreement would have been expected. June 1946 was described in the *Monthly Supplement to the Daily Weather Report* as "Dull, wet and cool . . . Although no unusually heavy daily amounts were registered there was an excessive number of days with rain . . . Rain was above normal in most places". June 1945 was described as "Mainly unsettled . . . Rather cool weather prevailed, mainly of a showery type". It thus seems possible that the ground characteristics at Northolt were affected by the ground being abnormally wet for the time of the year.

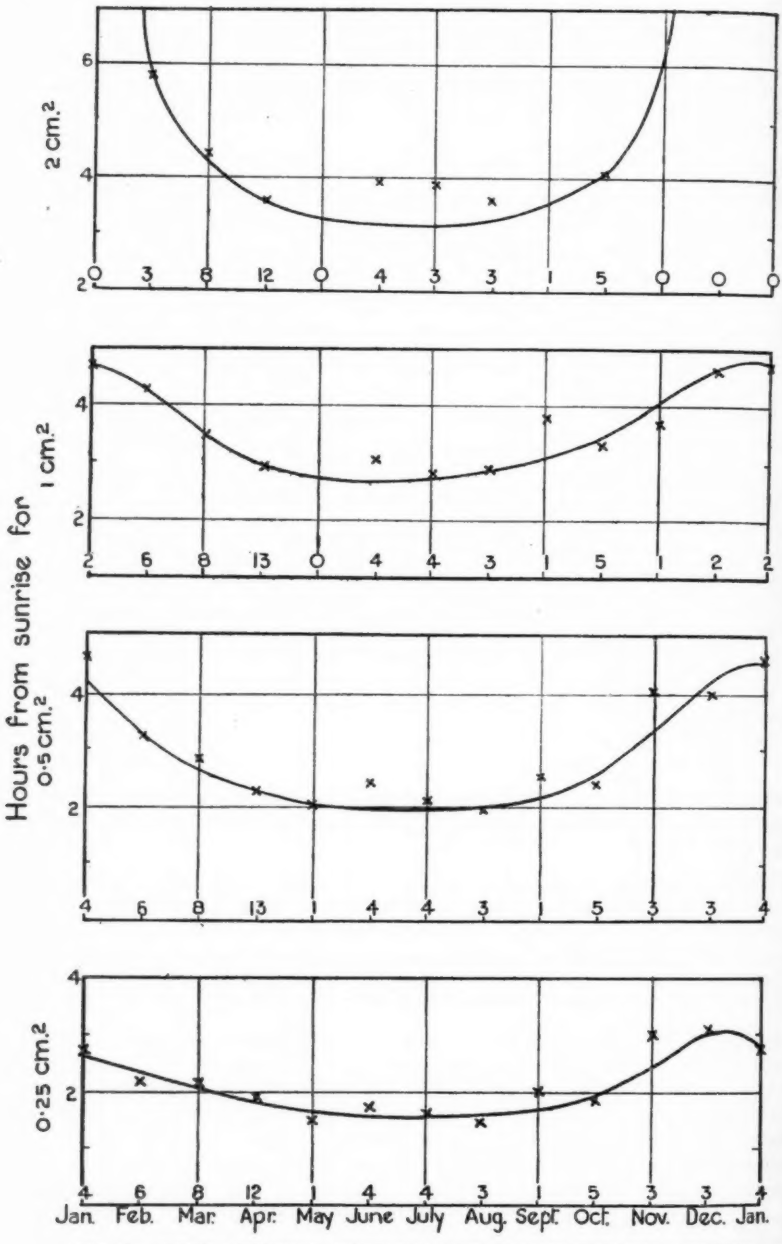

FIG. 3—CURVES SHOWING MONTHLY AVERAGES OF ENERGY PUT INTO THE LOWEST LAYERS OF AIR AT NORTHOLT BY SOLAR RADIATION

Number of occasions found in each month are shown at the base of the ordinate in each case

In drawing the curves more weight has been given to points which represent the largest number of days consistent with the general run of the curve. The points fit least well in the case of energy corresponding to 2 cm.^{2}. This can be expected since the diurnal curve has begun to flatten off by the time this amount of energy has been added, and variations in time at which any given temperature will be reached are magnified as compared with the earlier part of the heating period. For actual use corrected monthly mean values have been obtained from the smoothed curves. These are tabulated in Table II.

TABLE II

Energy equivalent	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	Average time from sunrise											
cm.^{2}	hours											
0·25	2·6	2·3	2·0	1·8	1·6	1·5	1·4	1·5	1·6	1·9	2·4	3·0
0·5	4·2	3·3	2·7	2·3	2·1	1·95	1·9	1·95	2·1	2·6	3·3	4·2
1	4·7	4·2	3·5	3·0	2·8	2·7	2·75	2·9	3·1	3·5	4·1	4·7
2	..	5·8	4·5	3·7	3·3	3·1	3·2	3·4	3·6	4·0	..	..

Practical examples.—In practice, the evaluation of temperatures which will be reached by adding the given amounts of energy demands some simple graphical method for the measurement of areas on the tephigram. A simple scale was scribed on a perspex sheet as shown in Fig. 4, in which the areas ABJ, ACH, ADG, and AEF are 0·25, 0·5, 1 and 2 cm.^{2} respectively. With this it is a simple matter to estimate the required temperatures: the line AE being laid along the surface pressure line the position of the scale is then adjusted until the correct position is found for the isothermal line AF for each standard area which is shown by the line EF in Fig. 4.

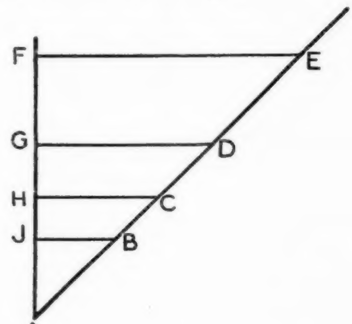

FIG. 4

The use of the monthly figures in drawing the forecast screen temperature curve is shown in Fig. 5 for four actual examples at different times of the year. All the days selected were characterised by clear or almost clear skies ; while one, December 12, 1946, had some shallow fog, the others had mainly good visibility throughout. There were no changes of air mass on any of the days.

The appropriate ascent for 0600 G.M.T. has been plotted for the four days in Fig. 5. The Northolt hourly minimum temperature has been added as an

additional point T and the estimated curve for Northolt drawn in the same way as described on p. 36. The points A, B, C, D in each figure correspond to the temperatures to be reached when the four standard amounts of energy have been added to the lowest layers.

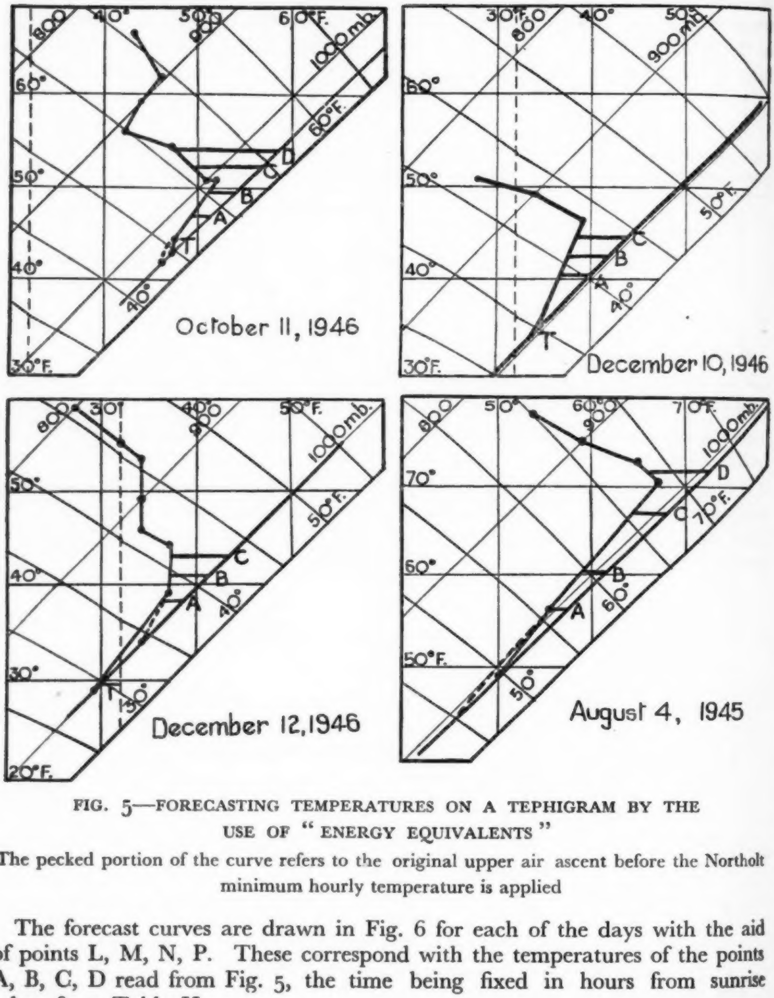

FIG. 5—FORECASTING TEMPERATURES ON A TEPHIGRAM BY THE USE OF "ENERGY EQUIVALENTS"

The pecked portion of the curve refers to the original upper air ascent before the Northolt minimum hourly temperature is applied

The forecast curves are drawn in Fig. 6 for each of the days with the aid of points L, M, N, P. These correspond with the temperatures of the points A, B, C, D read from Fig. 5, the time being fixed in hours from sunrise taken from Table II.

In each case the curves of the actual temperatures correspond reasonably well with the forecast curves. On October 11, 1946, it is noticeable how the actual curve falls furthest below the forecast curve at 0800 when there was 7–8 tenths of low cloud.

The maximum recorded on August 4, 1945, was 3 degrees above the estimated figure.

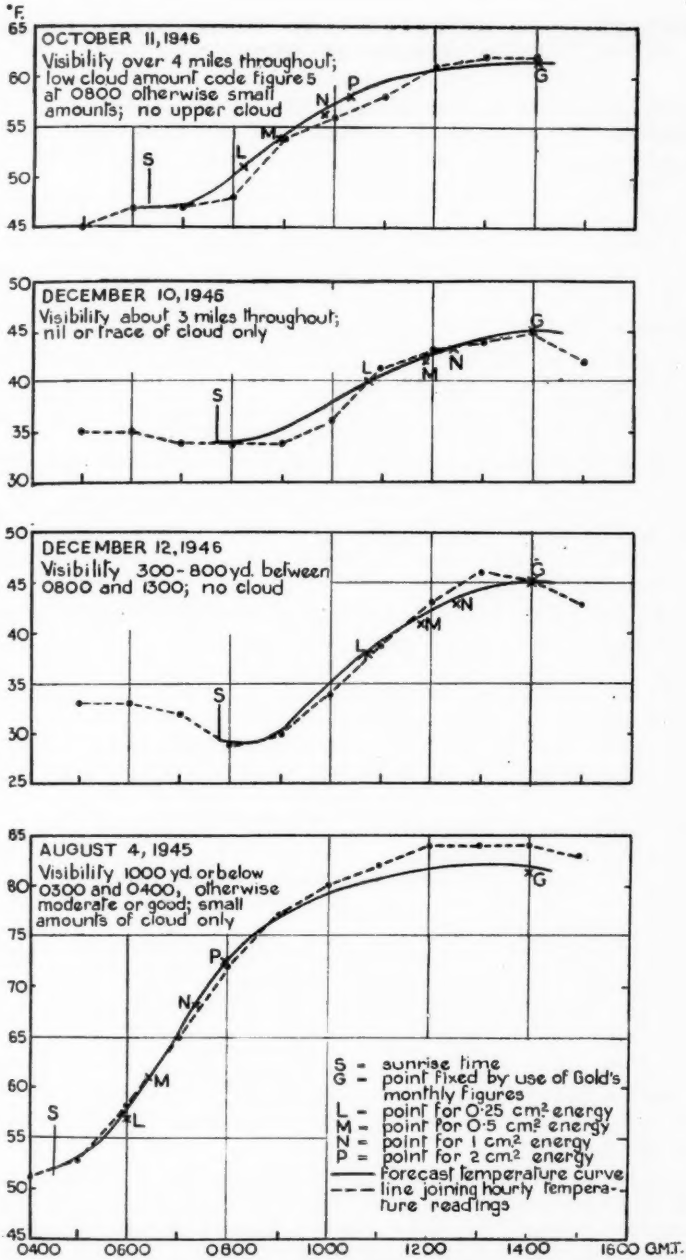

FIG. 6—COMPARISON OF FORECAST TEMPERATURES WITH HOURLY TEMPERATURE READINGS AT NORTHOLT

FREQUENCY OF RADIATION AND WIND FROSTS DURING SPRING IN KENT

By W. H. HOGG, M.Sc.

The distinction between a radiation frost and a wind frost is familiar to most fruit-growers. It is possible to provide some protection against radiation frosts but not against wind frosts, apart from the use of shelter to reduce convective heat loss from the buds or blossom.

A large capital outlay may be necessary to provide protection against frost, and therefore it is important to know what proportion of frosts occur with wind. In an attempt to provide this information the data from all available stations in Kent have been examined for the 30-year period 1919–48.

Definitions.—Although it is usually possible to distinguish the two types of frost, precise definitions have not so far been proposed. A screen frost is defined as a temperature of 32°F. or less ; in practice a temperature of 32·4°F. is generally used, as standard minimum thermometers are read to whole degrees. Recent work suggests that apple buds are damaged when the temperature falls below about 28°F., but the relation between screen temperature and bud temperature has not yet been investigated, and a screen minimum of 30°F. has been suggested by the East Malling Research Station as a convenient definition of frost for fruit-growers. To satisfy both meteorologists and agriculturists, and to allow for possible modifications of the definition, frequencies are given in 2-degree steps from 32° to 20°F.

For the definition of wind frost, East Malling Research Station has suggested that the term should be used when the wind speed exceeds 5 m.p.h. at a height of 30 ft. This is the equivalent wind speed for Beaufort force 2 which has therefore been adopted, as few stations are equipped with anemometers. The limits of speed at 30 ft. corresponding with Beaufort forces 2 and 3 are 4–7 m.p.h. and 8–12 m.p.h. respectively ; the frequencies are therefore based on a limiting wind speed of 7·5 m.p.h. instead of 5 m.p.h., but this is probably no disadvantage.

Effect of time of observations.—The definitions given above should refer to the minimum temperature and to the wind speed at the same time. At most climatological stations the only observations available are the minimum temperature and the wind speed at 0700 or 0900 G.M.T.* It is therefore necessary to allow for the following effects:—

(*a*) the increase in wind speed from the probable time of minimum temperature to the 0700 or 0900 observation. Unless some adjustment is made for this, the frequencies of wind frost will be over-estimated and those of radiation frost correspondingly under-estimated.

(*b*) the apparent difference in the frequency of frost days with different times of observation. When observations are made at 0700 a single frost is more likely to give rise to two frost days than when observations are made at 0900.

Observed frequencies have been adjusted for the diurnal variation of wind speed by factors based on mean hourly temperatures and wind speeds at Kew Observatory. The lowest mean hourly temperatures occur at about 0600 in March, 0500 in April and 0400 in May. Mean hourly wind speeds for

*All times are G.M.T.

1928–37 are given in Table I. The values refer only to those days when the mean hourly speed fell below 7·5 m.p.h. during hours centred on 0430, 0530 or 0630.

TABLE I—MEAN HOURLY WIND SPEED AT KEW ON MORNINGS WITH LIGHT BREEZE

Period: 1928–37

	0400	0500	0600	0700	0800	0900
			miles per hour			
March	..	3·6	3·7	4·1	4·8	6·1
April	..	4·0	4·3	5·1	6·3	7·5
May	3·7	3·7	4·3	5·2	6·3	7·1

In March, the wind speed can be expected to increase by 0·4 m.p.h. between 0600 and 0700, and a few radiation frosts may therefore be classified as wind frosts. The range of Beaufort force 3 is 7·5 to 12·5 m.p.h., and, assuming that the winds are distributed evenly throughout this range, 4/50 of the frosts which occur with a force-3 wind at 0700 have been included with the radiation frosts. For observations at 0900 the mean increase in wind speed since 0600 is 2·4 m.p.h. and 24/50 of the force-3 wind frosts have therefore been transferred to the radiation frosts. Similarly, the following factors have been adopted for other months : April 0700, 11/50; April 0900, 35/50; May 0700, 15/50; May 0900, 34/50.

The effect of time of observation on the recorded frequency of frost days has been investigated by Brooks*. The data in Table II have been taken from his table of 10-year frequencies of frost at Kew with different hours of setting and reading.

TABLE II—FROST FREQUENCIES AT KEW, 1928–37

Period	March	April	May
		number of occasions	
0700–0700	85	11	2
0900–0900	65	9	2
1800–0700	59	9	2
2100–0900	59	9	2

The last two lines give the frequency of night frost, which is the same whether observed between 1800 and 0700 or 2100 and 0900. This is probably the frequency in which the fruit-grower is most interested, for it is very unlikely that a frost during the day will not also be recorded in either the preceding or the following night. Also the use of night frosts avoids the risk of counting the same frost on two days, which occurs when the temperature is 32°F. or less at the morning observation. The first two lines show that this happens in March 6 times in 10 years with observations at 0900 only, and 26 times with observations taken at 0700; it is, of course, possible that on a few occasions the frost occurred during the day and not in the night. Thus no great error is introduced by combining or comparing frequencies of night frosts with those of 24-hr. frosts measured at 0900.

*BROOKS, C. E. P.; The effect of the hours of setting and reading the mininum thermometer on the number of screen frosts. Typescript, Meteorological Office, London, 1944.

Times of observation are included in Table III and these show that the frost frequencies refer mainly to night frosts or to frosts during the 24 hr. ending at 0900. No adjustments have been made in the frequencies, except for a few places where observations were taken only at 0700 for part of the period; these observations have been individually examined and the frequencies adjusted to allow for the occasions when it was likely that a single frost was responsible for the entries on two days.

Effect of period of observation.—The 30-year period 1919–48 has been used as the standard for these frequencies. For each month from March 1917 onwards rough estimates have been made of the amount by which the general temperature over the whole county differs from the mean for the period 1881–1915. From these, it can be estimated whether the data given in Tables IV–VI are likely to over-estimate or under-estimate the total frost frequencies over the standard period. Table III gives the probable effect of the period on the frequencies.

TABLE III—EFFECT OF PERIOD ON FROST FREQUENCIES

Station	Period	Time of observation	March	April	May
Biggin Hill	1921–40	1800, 0700	o	+	o
Manston	1929–48	1800, 0700†	+	o	+
Lympne	1921–48	1800, 0700†	o	o	o
Bromley	1927–48	0900	o	o	o
Canterbury	1931–44	0900	+	o	+
Tunbridge Wells	1919–48	0900†	o	o	o
Goudhurst	1935–48	0900†	+	—	+
East Malling	1925–48	0900	o	o	o
Wye	1925–48*	0900	o	o	o
Margate	1917–48*	0900†	o	o	o
Ramsgate	1916–48*	0900†	o	o	o
Deal	1922–48*	0900†	o	o	o
Dover	1912–48*	0900†	o	o	o
Folkestone	1914–48*	0900†	—	o	o
Dungeness	1918–48	1800, 0700†	o	o	o

+ Frequencies probably higher than for the standard period.

— Frequencies probably lower than for the standard period.

o Frequencies probably close to those for the standard period.

* Record incomplete.

† Times of observation have changed; the times given refer to most of the period.

Sites of stations.—The importance of local topography in relation to frost incidence is well known. A description of the surroundings of each station used is given below and each of the stations is allocated to one of four topographical types.

Hill-top sites.—Bromley, 213 ft. Just over the brow of a slope to the south-west which falls 40 ft. in 240 ft. Sheltered by buildings and best described as a sheltered hill-top site.

Biggin Hill, 567 ft. On top of a hill with a valley falling to about 400 ft. to the west and south-west. In other directions the ground is fairly level. The country generally is hilly and somewhat wooded.

Manston, 154 ft. A well exposed site near the centre of the Isle of Thanet.

Lympne, 346 ft. On top of the inner cliffs bordering Romney Marsh; to the south there is a steep drop of about 330 ft. beyond which the country is flat. About 2 miles from the sea.

Hill-side sites.—Canterbury, about 100 ft. In a residential area on the outskirts of Canterbury. On the lower slopes of the Great Stour Valley.

Tunbridge Wells, 351 ft. From 1919 to 1930 (approx.) a sheltered hill-top site. From about 1931 onwards the station has been in a sparsely built-up area; in a gully with the ground sloping moderately towards west-north-west.

Goudhurst, 390 ft. At the head of a valley, on a spur between two tributary valleys. In well-wooded country.

Plain sites.—East Malling, 132 ft. On the flank of a low escarpment. To the south the land rises some 130 ft. in ¾ mile; to the north-east it falls to the Medway, about 120 ft. in 1½ miles. There is a railway embankment 12–14 ft. high about 40 yd. to the south.

Wye, 164 ft. At the base of hills on a very slight spur. The Downs to the east and west rise above 500 ft.

Coast sites.—The observations were taken near the coast at the following places:—

	ft.		ft.
Margate	51	Dover	19
Ramsgate	80	Folkestone	128
Deal	18	Dungeness	20

These sites can be considered well-exposed except at Deal, where the observations were taken at a rather sheltered site for many years.

Estimated frequency of frost.—Tables IV–VI give the estimated frequencies of frost, radiation frost and wind frost, for minimum temperatures $\leqslant$32°F. $\leqslant$30°F. . . . . $\leqslant$20°F.*. The observed frequencies have been adjusted in the manner described on p. 43. Also, the proportion of wind frosts to total frosts (expressed as a percentage) is given for minimum temperatures $\leqslant$32°F. and $\leqslant$30°F.

The effect of site is clear from Tables IV–VI, where only Bromley and Dungeness appear anomalous. No doubt Bromley is anomalous because the site is more sheltered than those at other hill-top stations, but it is not evident why there should be more frost at Dungeness than at other coast stations.

In March, frost is least likely along the coast, more likely on hill-tops, and most likely on the hill-slopes and in the plains. For radiation frosts only, the different sites show the same relative susceptibility as for total frosts. Only 25–30 per cent. of frosts are wind frosts on the hill-sides and in the plains, compared with about 50 per cent. on the hill-tops and rather less along the coasts. Wind frosts are on the whole rather more frequent on the hill-tops than on the hill-sides or on the plains ; they are least frequent along the coast.

In April, frost is least likely along the coasts but there is no marked difference between the other sites ; this is true also for radiation frosts. Wind frosts also are least likely along the coasts where they constitute 35 per cent. or more of all frosts at most places ; some 35–45 per cent. of frosts on the hill-tops are wind frosts, and 10–30 per cent. on the hill-sides and plains.

* As minimum thermometers are read to whole degrees the exact temperature for which frequencies are given are $\leqslant$32.4°F., $\leqslant$30.4°F., ... $\leqslant$20.4°F.

In May the frequencies are low and little generalization is possible. Both radiation frosts and wind frosts are most frequent on hill-sides and plains.

Acknowledgements.—Acknowledgement is made to the staff of East Malling Research Station with whom this subject has been discussed, and in particular to Dr. W. S. Rogers of the Pomology Department; to the staff of the Agricultural Branch of the Meteorological Office who assisted with the computation and to the Climatological Branch of the Meteorological Office who made available the daily returns on which the investigation is based.

TABLE IV—MEAN FROST FREQUENCY IN MARCH

	Type of frost	≤32°	≤30°	≤28°	≤26°	≤24°	≤22°	≤20°
HILL-TOP					*days*			
Biggin Hill	Radiation	4·5	2·9	1·6	0·9	0·8	0·5	0·1
	Wind	3·8	2·1	0·9	0·2	0·1	0·1	0
	Total	8·3	5·0	2·5	1·1	0·9	0·5	0·1
	Wind/total (%)	46	42	..	..	..	..	..
Manston	Radiation	3·2	1·5	0·8	0·3	0·1	0	0
	Wind	2·9	1·3	0·6	0·3	0·1	0	0
	Total	6·1	2·7	1·4	0·6	0·3	0	0
	Wind/total (%)	48	46	..	..	..	..	..
Lympne	Radiation	3·5	1·9	0·9	0·3	0·2	0·1	<0·1
	Wind	4·2	2·1	1·2	0·6	0·5	0·2	0·1
	Total	7·7	4·0	2·1	0·9	0·6	0·3	0·1
	Wind/total (%)	54	52	..	..	..	..	..
Bromley	Radiation	7·0	4·1	2·3	1·3	0·7	0·3	0·1
	Wind	1·9	1·1	0·5	0·3	0·1	<0·1	<0·1
	Total	8·9	5·2	2·8	1·6	0·8	0·3	0·1
	Wind/total (%)	21	22	..	..	..	..	..
HILL-SIDE								
Canterbury	Radiation	7·4	5·4	2·9	1·4	0·7	0·4	0·1
	Wind	2·4	1·4	0·7	0·2	0·2	0	0
	Total	9·8	6·8	3·6	1·6	0·9	0·4	0·1
	Wind/total (%)	25	21	..	..	..	..	..
Tunbridge Wells	Radiation	8·4	6·2	4·1	2·3	1·2	0·6	0·4
	Wind	3·0	1·9	1·1	0·6	0·3	0·2	0·1
	Total	11·4	8·0	5·1	2·9	1·5	0·8	0·5
	Wind/total (%)	26	23	..	..	..	..	..
Goudhurst	Radiation	9·3	6·3	4·1	2·1	0·9	0·4	0·2
	Wind	3·4	2·1	1·2	0·6	0·4	0·3	0·1
	Total	12·6	8·4	5·4	2·8	1·2	0·7	0·3
	Wind/total (%)	27	25	..	..	..	..	..
PLAIN								
East Malling	Radiation	8·4	5·7	3·5	2·0	1·0	0·6	0·2
	Wind	3·1	1·7	0·7	0·4	0·2	0·2	<0·1
	Total	11·5	7·3	4·3	2·4	1·2	0·8	0·3
	Wind/total (%)	27	23	..	..	..	..	..
Wye	Radiation	7·5	5·1	2·7	1·7	0·8	0·5	0·3
	Wind	3·0	1·4	0·8	0·3	0·2	0·1	0·1
	Total	10·5	6·5	3·5	2·0	1·0	0·5	0·3
	Wind/total (%)	28	21	..	..	..	..	..
COAST								
Margate	Radiation	1·5	0·6	0·2	0·1	<0·1	0	0
	Wind	1·1	0·5	0·1	0·1	<0·1	0	0
	Total	2·6	1·1	0·3	0·2	0·1	0	0
	Wind/total (%)	41	44	..	..	..	..	..

TABLE IV—MEAN FROST FREQUENCY IN MARCH—*continued*

	Type of frost	≤32°	≤30°	≤28°	≤26°	≤24°	≤22°	≤20°
COAST—*contd.*					*days*			
Ramsgate	Radiation	2·1	0·8	0·3	0·1	<0·1	0	0
	Wind	1·4	0·6	0·2	0·1	0·1	<0·1	0
	Total	3·6	1·4	0·5	0·2	0·1	<0·1	0
	Wind/total (%)	40	45	..	..	..	..	..
Deal	Radiation	3·5	2·2	1·3	0·6	0·2	0·1	0·1
	Wind	1·9	1·1	0·4	0·1	0·1	<0·1	0
	Total	5·4	3·3	1·7	0·7	0·3	0·2	0·1
	Wind/total (%)	35	33	..	..	..	..	..
Dover	Radiation	2·0	1·2	0·6	0·2	0·2	0·1	<0·1
	Wind	2·0	1·0	0·3	0·2	0	0	0
	Total	4·0	2·2	0·8	0·4	0·2	0·1	<0·1
	Wind/total (%)	51	47	..	..	..	..	..
Folkestone	Radiation	2·1	0·9	0·3	0·2	0·1	<0·1	0
	Wind	2·3	1·2	0·5	0·2	0·1	0·1	0
	Total	4·4	2·0	0·9	0·4	0·3	0·1	0
	Wind/total (%)	53	57	..	..	..	..	..
Dungeness	Radiation	4·6	3·6	1·9	1·1	0·6	0·3	0·1
	Wind	2·3	1·3	0·6	0·4	0·1	0	0
	Total	6·9	4·9	2·5	1·5	0·7	0·3	0·1
	Wind/total (%)	33	27	..	..	..	..	..

Entries of <0·1 indicate frequencies >0 and <0·05.

Apparent discrepancies are due to the fact that the lines giving total frost frequency and wind/total (%) have been worked from the total frequencies and not from the mean frequencies of radiation and wind frost.

TABLE V—MEAN FROST FREQUENCY IN APRIL

	Type of frost	≤32°	≤30°	≤28°	≤26°	≤24°
HILL-TOP				*days*		
Biggin Hill	Radiation	2·7	1·0	0·4	0·1	0
	Wind	1·3	0·4	0·1	0	0
	Total	4·0	1·4	0·5	0·1	0
	Wind/total (%)	34	29	..	..	..
Manston	Radiation	0·8	0·3	0	0	0
	Wind	0·5	0·1	0	0	0
	Total	1·3	0·5	0	0	0
	Wind/total (%)	37	29	..	..	..
Lympne	Radiation	1·2	0·7	0·3	0	0
	Wind	1·0	0·5	0·1	0	0
	Total	2·2	1·1	0·3	0	0
	Wind/total (%)	45	41	..	..	..
Bromley	Radiation	1·5	0·7	0·1	0	0
	Wind	0·8	0·3	0·1	<0·1	0
	Total	2·4	1·0	0·2	<0·1	0
	Wind/total (%)	35	32	..	..	..
HILL-SIDE						
Canterbury	Radiation	1·8	0·9	0·4	0·1	0
	Wind	0·2	0·1	0·1	0	0
	Total	2·0	1·1	0·4	0·1	0
	Wind/total (%)	11	13	..	..	..
Tunbridge Wells	Radiation	3·3	2·1	0·9	0·4	0·1
	Wind	1·2	0·7	0·2	0·2	<0·1
	Total	4·5	2·8	1·2	0·6	0·1
	Wind/total (%)	27	25	..	..	..

TABLE V—MEAN FROST FREQUENCY IN APRIL—*continued*

	Type of frost	⩽32°	⩽30°	⩽28°	⩽26°	⩽24°
HILL-SIDE—*contd.*				*days*		
Goudhurst	Radiation	3·4	2·1	1·1	0·3	0·1
	Wind	1·4	0·9	0·4	0	0
	Total	4·9	3·1	1·5	0·3	0·1
	Wind/total (%)	29	30	..	..	..
PLAIN						
East Malling	Radiation	2·9	1·6	0·5	0·2	0
	Wind	1·1	0·6	0·2	0	0
	Total	4·0	2·2	0·7	0·2	0
	Wind/total (%)	28	26	..	..	..
Wye	Radiation	2·5	1·3	0·5	0·2	0
	Wind	0·5	0·2	0·1	0	0
	Total	3·1	1·5	0·6	0·2	0
	Wind/total (%)	18	14	..	..	..
COAST						
Margate	Radiation	0·1	<0·1	0	0	0
	Wind	0·2	0·1	0	0	0
	Total	0·3	0·1	0	0	0
	Wind/total (%)	60	75	..	..	..
Ramsgate	Radiation	0·3	0·1	0	0	0
	Wind	0·4	0·1	0·1	0	0
	Total	0·7	0·3	0·1	0	0
	Wind/total (%)	53	57	..	..	..
Deal	Radiation	0·4	0·2	0·1	0	0
	Wind	0·3	<0·1	0	0	0
	Total	0·7	0·3	0·1	0	0
	Wind/total (%)	39	14	..	..	..
Dover	Radiation	0·5	0·2	<0·1	0	0
	Wind	0·1	0	0	0	0
	Total	0·6	0·2	<0·1	0	0
	Wind/total (%)	19	0	..	..	..
Folkestone	Radiation	0·4	0·1	0	0	0
	Wind	0·2	0	0	0	0
	Total	0·6	0·1	0	0	0
	Wind/total (%)	36	0	..	..	..
Dungeness	Radiation	1·9	0·9	0·3	0·1	0
	Wind	0·5	0·3	0·1	0	0
	Total	2·4	1·1	0·4	0·1	0
	Wind/total (%)	22	24	..	..	..

Entries of <0·1 indicate frequencies >0 and <0·05.

Apparent discrepancies are due to the fact that the lines giving total frost frequency and wind/total (%) have been worked from the total frequencies and not from the mean frequencies of radiation and wind frost.

TABLE VI—MEAN FROST FREQUENCY IN MAY

	Type of frost	⩽32°	⩽30°	⩽28°	⩽26°	⩽24°
HILL-TOP				*days*		
Biggin Hill	Radiation	0·2	0·1	0	0	0
	Wind	0·1	0	0	0	0
	Total	0·3	0·1	0	0	0
	Wind/total (%)	43	0	..	..	..
Manston	Radiation	0·3	0	0	0	0
	Wind	0·1	0·1	0	0	0
	Total	0·4	0·1	0	0	0
	Wind/total (%)	33	100	..	..	..

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RIME AT STONEHOUSE, GLOUCESTERSHIRE, JANUARY 26, 1945

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1869

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1933

ÅBREKKE GLACIER, JOTUNHEIM, SHOWING RECESSION

(see January 1950, p. 16)

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1946

ÅBREKKE GLACIER, JOTUNHEIM, SHOWING RECESSION

(see January 1950, p. 16)

PLOTTING A SYNOPTIC CHART AT THE CENTRAL FORECASTING OFFICE, DUNSTABLE, FOR USE ON THE AIRMET BROADCAST

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CORNER OF THE COMMUNICATIONS ROOM AT CENTRAL FORECASTING OFFICE, DUNSTABLE

Messages are received from the W/T room by an overhead conveyor belt and from the teleprinter room by a conveyor belt in the channel on the left of the picture.

TABLE VI—MEAN FROST FREQUENCY IN MAY—*continued*

	Type of frost	$\leqslant 32°$	$\leqslant 30°$	$\leqslant 28°$	$\leqslant 26°$	$\leqslant 24°$
HILL-TOP—*contd.*						
Lympne	Radiation	0·5	0·2	<0·1	0	0
	Wind	0·1	0	0	0	0
	Total	0·6	0·2	<0·1	0	0
	Wind/total (%)	18	0	..	..	..
Bromley	Radiation	0·5	0·3	0·1	0	0
	Wind	0·1	0·1	0	0	0
	Total	0·6	0·4	0·1	0	0
	Wind/total (%)	21	33	..	..	..
HILL-SIDE						
Canterbury	Radiation	1·0	0·4	0·1	0	0
	Wind	0·1	0	0	0	0
	Total	1·1	0·4	0·1	0	0
	Wind/total (%)	7	0	..	..	..
Tunbridge Wells	Radiation	0·7	0·4	0·2	0·1	0
	Wind	0·3	0·2	0·2	<0·1	0
	Total	1·0	0·6	0·4	0·1	0
	Wind/total (%)	32	33	..	..	..
Goudhurst	Radiation	2·0	1·1	0·6	0·3	0·1
	Wind	0·7	0·5	0·1	0	0
	Total	2·7	1·6	0·7	0·3	0·1
	Wind/total (%)	26	30	..	..	..
PLAIN						
East Malling	Radiation	1·5	0·9	0·4	0·1	0
	Wind	0·5	0·3	0·1	0·1	0
	Total	2·0	1·2	0·5	0·2	0
	Wind/total (%)	23	25	..	..	..
Wye	Radiation	1·1	0·6	0·2	0·1	0
	Wind	0·2	0·1	<0·1	0	0
	Total	1·3	0·7	0·2	0·1	0
	Wind/total (%)	14	13	..	..	..
COAST						
Margate, Ramsgate, Folkestone				Nil		
Deal	Radiation	0·1	<0·1	0	0	0
	Wind	0·1	0	0	0	0
	Total	0·2	<0·1	0	0	0
	Wind/total (%)	40	0	..	..	..
Dover	Radiation	<0·1	0	0	0	0
	Wind	0	0	0	0	0
	Total	<0·1	0	0	0	0
	Wind/total (%)	0	—	..	..	..
Dungeness	Radiation	0·4	0·3	0·1	<0·1	0
	Wind	0·1	<0·1	<0·1	0	0
	Total	0·5	0·3	0·1	<0·1	0
	Wind/total (%)	19	10	..	..	..

Entries of <0·1 indicate frequencies >0 and <0·05.

Apparent discrepancies are due to the fact that the lines giving total frost frequency and wind/total (%) have been worked from the total frequencies and not from the mean frequencies of radiation and wind frost.

ERRATUM

January 1950, page 20, line 30; *delete* "over which there was stable air."

METEOROLOGICAL OFFICE DISCUSSION

December 5, 1949. The significance of three-dimensional weather analysis in forecasting. By R. Scherhag (Neue Methoden der Wetteranalyse und Wetterprognose, Berlin, 1948, p. 318.) Opener—Mr. J. L. Galloway.

Dr. J. M. Stagg, Principal Deputy Director of the Meteorological Office, intimated the Director's regret at being unable to be present, and called on Mr. J. L. Galloway to open the discussion.

Mr. Galloway stated that it was not his purpose to attempt to review the whole of Scherhag's book. Reviews had already appeared in the *Meteorological Magazine*[1*] and the *Quarterly Journal of the Royal Meteorological Society*[2]. He proposed to confine himself to those parts of the book in which Scherhag dealt with the use of upper air data in forecasting.

In Mr. Galloway's view, the differences between our own forecasting technique and that of the Germans were more a matter of practice than principle. Like ourselves, the Germans worked on the concept of thermal steering, as embodied in upper flow patterns and thicknesses. It appeared to him, however, that the Germans had not progressed in regard to the former as far as had Dr. Sutcliffe and his colleagues in the Forecasting Research Division at Dunstable; German effort had rather been directed towards the stratosphere where they had led us in the development of the radio-sonde. Herein lay what he considered was the main difference between the two techniques; the Germans had extended the scope of Bjerknes' rule, that a depression moved in the direction parallel to the surface isobars in the warm sector, to the generalization that a depression was steered by the pressure pattern at the lowest level which it did not disturb. Thus, while in both techniques the contours of the 500-mb. level were used for steering, the Germans had no hesitation in using the contours for a higher level, when, as sometimes happened, use of the 500-mb. contours presented difficulties.

Mr. Galloway had been struck by the absence from the book of reference to any new theory. On the contrary, Scherhag had here and there claimed that the new upper air observational data had confirmed propositions, both theoretical and empirical, put forward in Germany years before. Scherhag's own theory of divergence, which had given him an international reputation, had been published in the early 1930's, before upper air charts were available. Scherhag had re-emphasised that simple fanning of isobars did not in itself constitute divergence; for this a removal of air was required. Ryd's postulate had provided a working hypothesis; Ryd had shown in 1927[3] that the deceleration which took place in such a situation caused in the northern hemisphere a deviation of the stream-lines toward higher pressure. Scherhag had applied this to account for cyclogenesis on the low-pressure side of what the Germans called the " delta " (exit) of a " frontal zone " which, in their terminology, was the zone of transition between two air masses of different origin which were in contact along a length of at least 1,000 Km. In this context we would have expected a discussion of jet streaming, but, although Scherhag was aware of the high winds experienced at upper levels in frontal zones, this was a term he did not use.

Another term, introduced by Mollwo in 1936[4], but unfamiliar to British meteorologists, was " stratospheric compensation ". This was applied to a

*The index numbers refer to the list of references on p. 54

number of empirical relationships which the Germans had developed between the temperature of the stratosphere and various parameters, *e.g.* the pressure at the surface and other levels, but Scherhag had not indicated whether this work had any general short-term prognostic value. One German writer[5] had found 11- and 22-day periodicities persisting for $3\frac{1}{2}$–5 periods in departures from normal stratospheric compensation at Jever during the winter of 1947–48. In this connexion it was interesting to note that it had been suggested in America[6] that density change in the layer 2–3 Km. above the tropopause contributed most to pressure change at the surface.

The working methods used by the Germans in the routine construction of prebaratics were as follows:—

Surface prebaratics. The charts required were the analysed surface chart, the absolute and relative charts of the standard upper surfaces and the 24-hr. and 3-hr. isallobaric charts.

The basic data were the 24-hr. isallobars and the 500-mb. absolute contours. Arbitrary points on the isallobaric chart were advected in accordance with the direction and 50–60 per cent. of the speed given by the absolute contours at the chosen level. Changes in the isallobaric field were estimated from the pattern of the contours in accordance with empirical rules developed by Scherhag and others. The resulting pattern was smoothed to eliminate any features known to be impossible in nature. The forecast isallobaric chart was then added to the surface chart. A further adjustment might be necessary to fit in the surface fronts.

Upper-level prebaratics. The contours of the absolute topography were obtained by adding the forecast thicknesses to the surface prebaratic. In forecasting the change of thickness, consideration was given to the effects of radiation, convection and other vertical motions, and advection. The effect of radiation was negligible. The effects of convection, which might cause an error of up to 20 dynamic dekametres over the sea in winter, and of other vertical motions were not negligible and were not easily measurable. They were allowed for by adjusting the speed of advection, itself the most important single factor and the most readily susceptible to calculation, in accordance with the rule that the displacement of the relative isopleths was to a first approximation due to the gradient wind just above the surface friction layer and took place at a speed equal to 80 per cent. of the geostrophic value at that level.

Slides were then shown of three cases discussed by Scherhag:—

(*a*) December 5–6, 1942—stratospheric steering and influence on development.

(*b*) March 18–19, 1944—construction of prebaratics for March 19, illustrating the effect of (i) upper divergence and upper convergence and (ii) increase of horizontal temperature gradient.

(*c*) May 26–27, 1944—anticyclogenesis due to geostrophic departures.

In conclusion, Mr. Galloway said that Scherhag looked for improvement in the accuracy of forecasting to a better understanding of geostrophic departures which would come from a denser network of upper air stations.

Dr. Stagg, opening the discussion, said he wanted to know what use the Germans made of the departures from the normal stratospheric compensation.

Mr. C. S. Durst said that the charts mentioned were all available in the German daily weather reports. He expressed grave doubts as to whether these charts were as accurate as those now being published in the United Kingdom.

Mr. C. K. M. Douglas referred to the pioneer work carried out by the German meteorologists in the 1930's in the construction and interpretation of upper air charts, an achievement in which Dr. Scherhag had played a prominent part. The large number of aeroplane soundings made in Germany at that time had provided an opportunity of which good use had been made. He had always felt that the real value of empirical forecasting rules was somewhat limited. Thermal steering was an old principle, as Scherhag had pointed out, and there was obviously a real foundation for it, but if applied without great caution it might damage rather than improve the forecasts. A real advance would have to be based on an understanding of the dynamical and physical processes underlying the observed changes. He thought that the work carried out by Dr. Sutcliffe and his collaborators in the Forecasting Research Division had already rendered obsolete most of that part of Scherhag's book (only a fraction of the total) which dealt with forecasting. Although there was no doubt about the great importance of ageostrophic winds, it was premature to suppose that they could be applied directly to forecasting at present. In the case of May 26, 1944, if the British soundings were taken into account, the upper winds as plotted in the German daily weather report for that day gave no evidence of an outstanding or calculable ageostrophic motion. The alleged stratospheric steering, on December 5–6, 1942, was equally open to doubt. The rapid advance of the wedge could be better explained by the strong anticyclonic pattern in the 1000–500-mb. thicknesses associated with the very warm air to westward, which was rapidly approaching. Our own experience had shown conclusively that it was essential to take into account not only the existing thermal and flow patterns but also the probable future structure before the prebaratic was completed. The ideal plan was to make a rough prebaratic, then a pre-thickness chart based on it, and finally to adjust both together, but the clock was a limiting influence. The errors in a prebaratic increased in a roughly linear ratio to the time interval to which it referred, and if it was delayed too long its value was reduced. The high standard of the greater part of the book suggested that its author was more at home on the solid ground of fact than the quagmire of so-called forecasting rules. The book would be of value to meteorology even if it did not affect forecasting in this country. It would be a task of extreme difficulty to produce a text-book which could really influence forecasting.

Dr. R. C. Sutcliffe agreed that the slavish use of forecasting rules was unsatisfactory. Scherhag was an empiricist, but he had a reputation, outside as well as inside Germany, of being a very good practical forecaster. Dr. Sutcliffe missed any plausible general theory of forecasting in the book. The Germans had found cyclogenesis in the " delta " early in the 1930's and had made efforts to provide a theoretical foundation for it. Roediger had written on the vorticity aspect. Now the Germans had got away from pure frontal theory without considering dynamics. Scherhag had said nothing very clearly or effectively that was not already in our own vocabulary and we had little to learn from him. The area covered in his charts was far too small. The technique for the use of upper air charts had not yet been finally established, but at Dunstable

they had settled down to using the 500-mb. level. If more than one level were to be used, the work would become complicated. In any case he did not like the mentality which could say " the 500-mb. level doesn't seem to give the answer to-day, let us have a go with the 225- or even 96-mb. level ". A paper on the use of upper charts had recently been completed at Dunstable and was being issued. The function of research was to feed professional forecasters with ideas ; it would be impossible to write a complete text-book of forecasting smaller in compass than the " Encyclopaedia Britannica".

Mr. J. S. Sawyer said that the broad lines of Scherhag's technique, although largely empirical, agreed with those developed at Dunstable from Dr. Sutcliffe's ideas. He pointed out the contrast between Scherhag's technique and that of Rossby who used the flow patterns for the 500- and 750-mb. levels.

Mr. E. Gold took exception to the statement about Scherhag's use for steering of the lowest level not affected by the disturbance being steered. He thought that this was absurd ; if the disturbance did not affect the level he did not see how the level could affect it. He inquired whether Scherhag had discussed the rate of decay of disturbances; Dr. Sutcliffe replied in the negative and remarked that it was time that the turbulence experts turned their attention to large-scale atmospheric friction.

Dr. Farquharson thought that the thickness-pattern method was more practically satisfactory than Scherhag's empiricism.

Mr. J. M. Craddock referred to Scherhag's appreciation of the problem of forecasting thickness change. In his view the effect of radiation was not negligible; in fact, it had been calculated by Brunt. The allowance for convection was, he thought from his own work, about right. He had also measured the advection contribution on 700 occasions for Downham Market, and had as a result formed the opinion, shared by the Upper Air Unit at Dunstable, that if change of thickness were to be allowed for by choice of the speed of advection of the isopleths, then 45 per cent. of the speed of the geostrophic wind just above the surface friction layer should be taken, not the 80 per cent. used by Scherhag.

Prof. P. A. Sheppard was disappointed that he had not learned more about " stratospheric compensation ". He sounded a warning note about the criticism of Scherhag's empiricism. Ryd had had the right ideas on the formation of depressions and these had been built on by Scherhag to give his work a theoretical basis. In any case all this took up only a small portion of a book which had to be regarded as a contribution of first importance to meteorological literature.

Dr. A. G. Forsdyke agreed that Scherhag had little to teach British forecasters, and supported Dr. Sutcliffe's view that only one parameter should be studied. Scherhag had failed to mention the effect of stability on disturbance development. Sumner had worked on this and had shown that the theory was in agreement with experience.

Mr. Galloway, in replying to the discussion (partly communicated) said that the Germans claimed for their radio-sonde an accuracy of more than twice that claimed by us for the Kew radio-sonde. The whole question of German requirements of accuracy of measurement in the upper air had been previously discussed in the Meteorological Office[7]. The completion of Scherhag's book

had been sponsored by the American Occupation authorities in Germany, and it was therefore all the more regrettable that the German war-time charts published in it had not been corrected and amplified by using the British upper air data. In reply to Dr. Stagg and Prof. Sheppard he said that the Germans had applied the departures from the normal stratospheric compensation to the problem of the general circulation, but they had not yet decided whether the stratosphere played a primary or secondary role in the day-to-day regime of the weather. They appeared to have made no progress from Ertel's position in 1932[8]. Dr. Sutcliffe had recently dealt with the problem of empiricism in forecasting[9] and had suggested that "the most fertile line for early practical results lay along the extension of established channels, somewhere between pure empiricism and pure theory, what we may call rational empiricism". He would like to add a final word—to the thickness school. Numerous empirical methods of getting near the future 30-hr. position of a depression had been tried out in the U.S. Weather Bureau[10] and better results had been obtained from the consideration of the surface isallobars than the upper contours.

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METEOROLOGICAL RESEARCH COMMITTEE

The seventh meeting of the Synoptic and Dynamical Sub-Committee of the Meteorological Research Committee was held on November 17, 1949.

Methods of analysing upper air observations climatologically were considered, especially the difficulties at the 200-mb. level due to the large variations in temperature which are related with variations in tropopause height. Day-to-day forecasting for the 200-mb. level was also discussed.

A paper on the advective temperature changes in the troposphere by Mr. J. M. Craddock[1] and some comments on it by Dr. A. H. R. Goldie[2] were discussed at length. The former paper provides data which should prove useful to the forecaster.

The errors of radar wind observations on ocean weather ships were also considered.

The eighth meeting of the Physical Sub-Committee was held on November 9.

The research programme of the Meteorological Research Flight was considered, and the Committee heard of the development of two new types of aircraft thermometer with smaller lag than the routine instrument. It was agreed that, in future, high-level ascents by the Flight for the purpose of measuring humidity should be made only in selected synoptic situations.

The present position of knowledge of the size of water drops occurring in nature was reviewed and it was agreed to lower the priority of this work.

Two papers by Mr. F. Pasquill, one dealing with evaporation from grassland[3] and the other with the aerodynamic drag of grassland[4], were considered.

The Committee also discussed clear-air turbulence and its effect on aircraft and the measurement of turbulence in the high atmosphere.

[1] *Met. Res. Pap., London,* No. 517
[2] *Met. Res. Pap., London,* No. 518
[3] *Met. Res. Pap., London,* No. 498
[4] *Met. Res. Pap., London,* No. 503

ROYAL ASTRONOMICAL SOCIETY

A discussion on "Energy exchanges between the sea and the atmosphere" was held in the rooms of the Royal Astronomical Society on October 28, 1949 with Dr. G. E. R. Deacon, F.R.S., in the chair.

In his opening remarks Dr. Deacon mentioned that the problem of the energy exchange between the sea and the atmosphere was one which deeply concerned meteorologists and oceanographers alike. Whereas the meteorologist might say that the ocean received its energy from the atmosphere in the form of waves and currents the oceanographer in turn might say that the atmosphere largely derived its source of energy from the warmth of the oceans.

Prof. P. A. Sheppard opened the discussion by saying that the "air-ocean" was a mutually-reacting system. He discussed the equation of energy exchange between sea and air and estimated the magnitude of each term.

The stress coefficient had been computed using values of the strength of the wind on the water surface calculated from observations of the mean tilt of Lough Neagh in Northern Ireland. The stress coefficient agreed fairly well with other observations. It increased with unstable temperature gradient and decreased with stable gradient.

Mr. H. F. Bowden dealt with the hydrodynamical approach to the problem of heat exchange between the atmosphere and the sea and with practical attempts to apply the energy-balance equation.

Amongst contributors to the discussion were Mr. Charnock who described the Lough Neagh experiments and Prof. Neiburger who doubted the accuracy of the terms in the energy-balance equation. For example, the insolational term did not take into account reflection from clouds. Mr. Gold gave an interesting little calculation of the energy of waves breaking on the shore which, under assumptions of reasonable wave height and velocity, amounted to about 60 kilowatt-hours per centimetre of shore per day. This calculation served as an example to show that, although the energy derived from the frictional term in the energy-exchange equation was not negligible in itself, yet it could be neglected for Prof. Sheppard's purpose where the whole surface of the ocean was being considered.

Dr. Deacon, in summing up, said it was interesting to see how the actual routine observations made over the oceans could be of such use to meteorologists and oceanographers.

A. H. GORDON

PHYSICAL SOCIETY

Charles Chree Memorial Lecture

The Charles Chree Memorial lecture was given by Prof. G. M. B. Dobson before the Physical Society in the Science Museum on Friday November 4, 1949. The speaker was introduced by the President, Prof. G. I. Finch, who then presented Prof. Dobson with the Charles Chree gold medal and prize.

Prof. Dobson began entertaining the audience with reminiscences of Dr. Chree at Kew Observatory. Dr. Chree had always placed great emphasis on the importance of experimental evidence.

When he (the speaker) had known Dr. Chree at Kew, experimental facts were greatly lacking in all branches of meteorology, especially with regard to the upper atmosphere, and today there is still much work to be done in such subjects as atmospheric electricity, visibility and the light-scattering properties of the atmosphere.

The second part of Prof. Dobson's lecture consisted of a history of research into the ozone content of the atmosphere, a subject to which he has contributed so much. He concluded it with the interesting statement that Sir Charles Normand is now arranging for systematic world-wide observations to be made with the Dobson ozone spectrophotometer.

The last part of the lecture dealt with the measurement of the water content of the atmosphere at very low temperatures with the Dobson-Brewer frost-point hygrometer and the recent cloud-chamber work at Oxford by Cwilong and others on condensation processes.

Sir David Brunt, who spoke of his long association with the lecturer, proposed a vote of thanks to Prof. Dobson.

OFFICIAL PUBLICATIONS

British Rainfall 1940–42

This volume treats of the rainfall of Great Britain and Northern Ireland during the first three of the six war years when the annual publication of *British Rainfall* was suspended. The essential features of pre-war volumes have been retained in the new publication, but considerable curtailment and re-arrangement have been necessary to summarise adequately so many data within a single volume. The tabular matter is sufficiently complete to facilitate comparison with earlier years.

In Part I the distribution of rainfall in the months, the seasons and the year is considered in its relation to the average for 1881–1915. There are chapters on various features of rainfall, including spells of dry and wet weather, intense falls, duration of rainfall and evaporation. This part also includes 55 maps, of which three are coloured plates. The General Table, which forms Part II, gives the annual totals of rainfall and the numbers of rain days at nearly 5,000 stations which were maintained throughout the three years.

It is expected that the volume of British Rainfall for 1943–45 will be published shortly. The series up to the volume for 1946 will then be complete.

Average Annual Rainfall over Great Britain

Maps of average annual rainfall, 1881–1915, over Great Britain on a scale of about 10 miles to 1 inch have now been published by the Ordnance Survey.

Sheet 1 covers Scotland and northern England as far south as Ravenglass to Scarborough, and Sheet 2 the remainder of England and Wales. They are published in colour and cost 5*s.* 0*d.* net. each.

The first attempt at a rainfall map of the British Isles appears to have been that published by Mr. Joseph Atkinson of Harraby, near Carlisle, in 1841 or 1842. Petermann's "Hydrographical Map of the British Isles", published in July 1849, gives plotted averages for 113 places, practically all of which had less than 50 in. Later a small-scale map was published in Bartholomew's "Physical Atlas" Vol. III, 1899, giving isohyetal lines for 25, 30, 40, 60 and 80 in. This now can be regarded as little more than a sketch map depicting the relatively dry and wet areas.

The present map replaces that published in the "Rainfall Atlas of the British Isles" by the Royal Meteorological Society in 1926, on a scale of 60 miles to 1 inch, drawn originally in the Meteorological Office, on a scale of 19 miles to 1 inch. It was appreciated at the time that the ideal arrangement was to prepare maps on a scale of 2 miles to 1 inch, but that this would take a good deal of time. In order to produce a map for the Atlas quickly various short cuts were adopted. The isohyetal lines were based on information obtained from three sources:—

(*a*) Averages for 1881–1915 for 578 stations prepared in the Meteorological Office and published in the "Book of Normals", Section V.

(*b*) Maps on a scale of 2 miles to 1 inch prepared by Dr. H. R. Mill for the Geological Survey between 1908 and 1916. The averages were usually for the 35 years 1868–1902 and the lines were modified to fit the values for 1881–1915 by reference to the available averages over the area for the later period. These maps covered in all about half the area of the British Isles.

(*c*) Weighting decadal means for stations not covered under (*a*) to give approximate values for 1881–1915. This gave some 1,100 averages. In all the map was based on averages, actual or computed, for some 3,000 stations. It is interesting to recall that when this map was published initially* an estimate was given that the time taken by the observers in making the daily observations to enable the average rainfall map to be prepared was equivalent to a year's work for 500 men. A tribute should therefore be paid to the patient work of the large body of voluntary rainfall observers, and their public spirit in forwarding a copy of their readings to the Meteorological Office, which makes possible the preparation of the rainfall maps.

The distribution on the present map is indicated by means of isohyetal lines for 20, 22·5, 25, 27·5, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 120 and 150 in., the heavier rainfall being indicated by darker shades of blue. The fluctuations of monthly rainfall at representative stations are shown by means of dispersion graphs. There are 16 such graphs on Sheet 1 and 10 on Sheet 2. For each such station the monthly amounts within the period 1881–1915 are represented by dots. The monthly averages, the median (or mean value) and the upper and lower quartiles are also indicated.

The isohyetal lines were originally prepared in the Meteorological Office on a scale of 2 miles to 1 inch. In order to retain as much detail as possible the isohyetal lines were copied first, by the Ministry of Town and Country Planning, on

*See *Quart. J. R. met. Soc., London*, **47**, 1921, p. 101.

to maps on a scale of 4 miles to 1 inch before preparing the final copies for reproduction. The rainfall survey on a scale of 2 miles to 1 inch, using the mean 1881–1915, was commenced soon after 1920 and gradually extended county by county to cover the 74 sheets of the Ordnance Survey of Great Britain on this scale. Where a record was complete for the 35 years, 1881–1915, the mean annual amount was used. Wherever a rainfall record had been maintained for a shorter period, but for at least five years, the probable annual average, 1881–1915, was computed by multiplying the observed mean by a factor, derived from adjacent long records, to make allowance for the short record having either a preponderance of wet or dry years. Records maintained both before 1881 and after 1915 were used. The procedure is explained in an article on "The Rainfall of Norfolk", *British Rainfall*, 1928 (p. 270). In all, averages were computed for some 20,000 stations in the United Kingdom. The article in *British Rainfall*, 1933 (p. 266) on the rainfall of the County of London shows that averages can be obtained of sufficient accuracy to draw isohyetal lines at intervals of 1 inch, but in the mountainous regions the variation in the rainfall from place to place is often so great, and the records relatively so few, that it is only practicable to draw the lines at greater intervals. In the regions of heavier rainfall the isohyetal lines are therefore likely to require revision as more information becomes available.

Before the maps could be drawn with any degree of confidence it was necessary to have a clear picture of the errors arising in rainfall recording, and also of the relation of the distribution of rainfall to the orography. The inspection of numerous rain-gauges and examination of their records enabled the extent of any errors to be defined quantitatively and those of appreciable magnitude to be eliminated. The main source of error arose from abnormal exposures, especially on windward slopes, so that many mountain rain-gauges had to be inspected and often more orthodox sites selected. The second technique was developed by studying the distribution in areas of abundant data and applying this knowledge to areas of few records. The most exciting occasions involved making a forecast, for water-supply schemes, of the probable distribution over a mountainous catchment area with no records, setting up rain-gauges, and, when 5–10 years' records became available, plotting the computed averages and noting what modifications were necessary in the original provisional distribution. In the same way when a gauge was moved, the effect on the catch was closely studied to see whether the distribution on the map required modification. This is one of the reasons why the preparation of the complete rainfall survey of Great Britain has been spread over so long a period.

The present map, which itself has taken some 30 years to complete, may be regarded as the fulfilment of an ambition conceived more than 100 years ago. It is the result of the steady application of the British Rainfall Organization, Meteorological Office. Credit is also due to the Maps Section of the Ministry of Town and Country Planning and to the Ordnance Survey for the excellent reproduction.

J. GLASSPOOLE

LETTER TO THE EDITOR

Definition of relative humidity

The definition of relative humidity given in Resolution 166 of the Conference of Directors, Washington, 1947 is as follows: "The relative humidity U (in

per cent.) of moist air is defined by $U = 100r/r_w$ where r is the mixing ratio of moist air at pressure p and temperature T, and r_w is the saturation mixing ratio at the same pressure and temperature ".

It follows from this and the definitions of r, r_w and of vapour pressure that

$$U = \frac{e'}{e} \times \frac{p-e}{p-e'} \times 100$$

where e' is the actual vapour pressure and e is the saturation vapour pressure.

Hitherto U has been defined either (*a*) as the ratio (expressed as a percentage) of the water vapour actually present in unit volume to that contained in unit volume of saturated air at the same temperature, or (*b*) as $100e'/e$. These are identical over the range of values of temperature of water vapour for which Boyle's law, $pv =$ const., applies.

They are both materially different from the new value. For example at a temperature of 80°F. and pressure 1000 mb. and a vapour pressure of 17·5 mb. the new definition gives 49 per cent. instead of 50 per cent. given by the former definitions. At a temperature of 120°F. and a vapour pressure of 58·4 mb. the corresponding figures are 47 per cent. instead of 50 per cent. Higher temperatures than 120°F. are not common meteorologically, but they may occur in other connexions where relative humidity is significant, and it would not be desirable to have a different definition for these higher temperatures. At 185°F. and a vapour pressure of 350 mb. the new definition gives 23 per cent. against 50 per cent. by the old definitions.

If the total pressure p were 500 mb. instead of 1000 mb. the difference between the old and new values of relative humidity would be even more marked.

It seems unlikely that so great a change from past practice was intended and perhaps there is some other interpretation of the new definition.

E. GOLD

8 Hurst Close, London, N.W.11, November 25, 1949

NOTES AND NEWS

Universal Decimal Classification

551·5 Meteorology

In 1935 the Meteorological Section of the Universal Decimal Classification was greatly improved and enlarged by the Commission for Bibliography and Publications of the International Meteorological Organization, and was recommended for general use by the Conference of Directors at Warsaw that year by Resolution Warsaw 1935 : 101. It was brought into use in the Meteorological Office Library on January 1, 1936.

The classification as arranged in 1935 is described in publications numbered 1, 2 and 3, in the list of references on p. 60. A few additions were made at Berlin in 1939 by Resolution Berlin 1939 : 39 of the International Meteorological Committee and the amended classification as it existed from then onwards until 1949 is given in reference 4.

The progress of meteorology since 1939 has naturally necessitated a revision of the classification and the necessary changes were worked out by the Commission at its meeting at Toronto in September 1947. The proposals made (reference 5) were accepted by the Conference of Directors at Washington

in October 1947 in Resolution Washington 1947 : 120, and were then discussed between the Commission and the International Federation of Documentation which is responsible for securing that the classifications of individual subjects in the Universal Decimal Classification are in conformity with the general plan. Certain amendments of detail were made as a result of these discussions and the International Meteorological Organization is to publish an amendment to Publication 61 describing them.

The revised classification will be brought into use by the Meteorological Office Library for classifying books and papers received on and after January 1, 1950. By agreement with the British Standards Institution, which holds the copyright of the Universal Decimal Classification in Great Britain, a mimeographed copy of the revised classification has been sent to all recipients of the Library's Monthly Bibliography.

The major changes are those made to allow of more detailed classification in:—

551.501. *Methods of Observation.* New numbers added under 551.501.8 to cover meteorological observations by radar and location of sources of atmospherics.

551.507. *Apparatus and methods for carrying or supporting meteorological instruments.* New group added to cover special balloons, aircraft, etc.

551.508. *Meteorological instruments.* Additions to cover new instruments, such as cloud searchlights, and radar instruments.

551.509. *Weather forecasts and other applications.* Detailed expansion especially of 551.509.6 artificial influences (*e.g.* protection against frost, fog dispersal).

551.521. *Radiation and temperature.* Expansion, to give more exact distinction between radiations of different wave-lengths.

551.557. *Upper winds.* Expansion, to cover diurnal, annual and secular variations, frequencies and wind roses.

551.558. *Vertical component of air motion.* This is a new group.

551.584. *Microclimatology.* Addition of a detailed subdivision, and of "Mesoclimatology".

551.586. *Bioclimatology.* This group has been subdivided in detail.

551.589. *Synoptic climatology.* A new group has been added to cover this concept.

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4. Lausanne, Organisation Météorologique Internationale. Répertoire des résolutions de l'Organisation Météorologique Internationale, Appendix I. *Publ. Org. mét. int. Lausanne,* No. 50, 1943, p. 293.
5. Lausanne, Organisation Météorologique Internationale. Commission de bibliographie et de publications. 2me session, Toronto, Canada, 1947, Rapport final abrégé. *Publ. Org. mét. int., Lausanne,* No. 61, 1949. This publication will, it is understood, be amended to incorporate the changes agreed with the Fédération Internationale de Documentation.

NEWS IN BRIEF

The following awards to members of the staff of the Meteorological Office were announced in the New Year Honours List, 1950:—

O.B.E.

Mr. R. P. Batty. Assistant Director.

M.B.E.

Mr. A. M. Young. Experimental Officer, serving with British Air Forces of Occupation, Germany.

OBITUARIES

Mr. Arthur Eastwood.—We regret to learn of the death on October 7, 1949, in his ninetieth year, of Mr. Arthur Eastwood. In 1901 Mr. Eastwood set up a rain-gauge at Leigh Court, Angersleigh, and maintained records there continuously until June 1946, when he moved to Trull, two miles nearer Taunton. He continued to record daily rainfall measurements and personally wrote out and sent copies of the observations to the Meteorological Office to within a month of his death.

Mr. William Melvill Coode.—The death on October 26, 1949, of Mr. W. M. Coode, in his eighty-fourth year, removes from the ranks of rainfall observers one whose interest in weather recording extended over more than half a century. Since 1898 Mr. Coode had carried on without a break the rainfall record which his father commenced at St. Austell, Trevarna, in 1864. The records have been included in the annual volumes of *British Rainfall* for more than eighty years. This long homogeneous record was selected for use in many investigations, *e.g.* the percentage of average annual rainfall falling in the driest and wettest groups of consecutive months of varying length.

WEATHER OF DECEMBER 1949

Mean pressure was between 1020 and 1025 mb. in an area which included part of western France, the Azores, Bermuda, Nova Scotia and the eastern half of the U.S.A., and which reached the Pacific coast of America in about latitude 42°N. Over much of this area mean pressure was from 3 to 7 mb. above the average. Mean pressure was generally below 1000 mb. in an area bounded by Greenland in the west and the Gulf of Bothnia in the east and extending from northern Scotland nearly to Spitzbergen; over the part of this area lying between Iceland and northern Norway it was below 995 mb., and was 10 mb. or more below the average.

The weather over the British Isles was mainly mild, with southerly or westerly winds predominating. It was drier than usual south of an irregular line stretching from the Humber to Pembrokeshire and in a narrow coastal belt in east Scotland. It was very dry (less than half the average) over much of south-west England and in the neighbourhood of Aberdeen. On the other hand it was very wet in the west and north, particularly in an area extending from the north of Scotland to south Lancashire, over an inland area in north Wales and in County Tyrone.

During the opening days depressions moved north-east or east off the north of Scotland, while troughs or secondary depressions crossed the British Isles. The secondary which moved across north Ireland and north England on the 3rd and 4th was associated with gales, severe locally, and heavy rain in the north-west and west; for example, 2.20 in. at Blaenau Festiniog, Merioneth,

on the 2nd and 2·26 in. at Borrowdale, Cumberland, on the 3rd. On the 6th a depression in mid Atlantic rapidly approached the Hebrides and on the 7th it moved to north of the Shetlands and thence to north-west Norway; rain fell generally on the 6th and was heavy in the north-west (2·28 in. at Ardgour House, Argyllshire), while strong winds and gales occurred at exposed stations. In the rear of this depression a small polar disturbance formed off the north of Scotland on the 8th in a strong northerly air stream and subsequently moved south and later south-east over our western districts giving widespread snow or sleet; a blizzard was reported at Duntuilm on the 9th and there was heavy drifting in the western Highlands and on the Welsh Hills. The polar air caused a considerable fall in temperature over the country and the period 8th–11th or 12th was cold. On the 11th and 12th a wedge associated with the Azores anticyclone moved south over the British Isles; mainly fair weather prevailed over most of England and Wales but moderate rain occurred in north-west Scotland on the 11th and in Scotland and the north of Ireland on the 12th. On the 13th a trough moving south-east over the British Isles gave rain in most parts. Subsequently a mild, unsettled south-westerly type was renewed; on the 14th and 15th a secondary depression moved across Scotland giving almost general rain on the 14th and showers with local hail on the 15th, while on the 16th and 17th showery conditions prevailed as troughs to a depression near Iceland crossed the country. On the 18th and 19th a very deep depression moved from mid Atlantic across the north of Scotland; rainfall was general and heavy locally (2·35 in. at Ardgour House on the 19th) and there were widespread gales, severe in places, from the 17th–19th. On the 22nd an Atlantic depression moved north-east to Iceland where it remained, becoming less deep, until the 25th. Meanwhile an anticyclone over the Bay of Biscay moved east-north-east to Central Europe. A very mild air stream covered the British Isles; slight rain occurred generally on the 22nd but on the following days it was mainly dry in the south and east though rainfall was heavy at times in the north-west, notably on the 24th and 25th (3·51 in. at Ardgour and 2·97 in. at Onich on the 24th, 2·89 in. at Borrowdale and 2·20 in. at Blaenau Festiniog on the 25th). On the 26th yet another Atlantic depression moved north-east to the Shetlands causing further rain in the north-west and west. From the 27th–29th pressure was high over France and low to the north of the British Isles; dry weather prevailed for the most part in England and Wales but rain fell at times in Scotland and Ireland. During the closing days a deep depression off Portugal moved rather quick'y north off our western seaboard causing some rain in the extreme south-west of the British Isles, while feeble fronts caused rain locally in Scotland and north Ireland.

The general character of the weather is shown by the following provisional figures.

	Air Temperature			Rainfall		Sunshine	
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average	Percentage of possible duration
	°F.	°F.	°F.	%		%	%
England and Wales	59	23	+2·4	87	−1	121	21
Scotland	57	16	+0·2	143	+4	102	16
Northern Ireland..	54	22	+1·0	136	+4	79	13

RAINFALL OF DECEMBER 1949

Great Britain and Northern Ireland

County	Station	In.	Per cent of Av.	County	Station	In.	Per cent of Av.
London	Camden Square	1·40	59	*Glam.*	Cardiff, Penylan	4·18	83
Kent	Folkestone, Cherry Gdns.	2·09	65	*Pemb.*	St. Ann's Head	3·58	75
,,	Edenbridge, Falconhurst	1·48	45	*Card.*	Aberystwyth	4·73	119
Sussex	Compton, Compton Ho.	3·19	74	*Radnor*	Tyrmynydd	9·11	111
,,	Worthing, Beach Ho. Pk.	2·04	68	*Mont.*	Lake Vyrnwy	12·02	172
Hants.	Ventnor, Roy. Nat. Hos.	2·79	85	*Mer.*	Blaenau Festiniog	19·69	155
,,	Bournemouth	1·97	51	*Carn.*	Llandudno	4·09	141
,,	Sherborne St. John	1·70	52	*Angl.*	Llanerchymedd	4·49	102
Herts.	Royston, Therfield Rec.	1·59	69	*I. Man.*	Douglas, Borough Cem.	5·17	105
Bucks.	Slough, Upton	1·55	61	*Wigtown*	Port William, Monreith	5·09	112
Oxford	Oxford, Radcliffe	1·34	54	*Dumf.*	Dumfries, Crichton R.I.	7·05	165
N'hant	Wellingboro', Swanspool	1·44	61	,,	Eskdalemuir Obsy.	12·01	172
Essex	Shoeburyness	·98	53	*Roxb.*	Kelso, Floors	2·85	123
Suffolk	Campsea Ashe, High Ho.	1·65	72	*Peebles.*	Stobo Castle	6·02	158
,,	Lowestoft Sec. School	1·70	73	*Berwick*	Marchmont House	3·04	108
,,	Bury St. Ed., Westley H.	1·73	72	*E. Loth.*	North Berwick Res.	2·80	130
Norfolk	Sandringham Ho. Gdns.	1·57	62	*Midl'n.*	Edinburgh, Blackf'd. H.	3·85	165
Wilts.	Bishops Cannings	1·89	58	*Lanark*	Hamilton W. W., T'nhill	7·44	173
Dorset	Creech Grange	2·37	54	*Ayr*	Colmonell, Knockdolian	5·28	95
,,	Beaminster, East St.	1·81	38	,,	Glen Afton, Ayr San.	12·03	188
Devon	Teignmouth, Den Gdns.	1·47	35	*Bute*	Rothesay, Ardencraig	8·63	158
,,	Cullompton	2·13	48	*Argyll*	L. Sunart, Glenborrodale	12·63	145
,,	Barnstaple, N. Dev. Ath.	3·03	68	,,	Poltalloch	9·58	150
,,	Okehampton, Uplands	3·78	54	,,	Inveraray Castle	18·01	181
Cornwall	Bude School House	2·93	67	,,	Islay, Eallabus	8·80	148
,,	Penzance, Morrab Gdns.	4·06	71	,,	Tiree	6·90	132
,,	St. Austell	3·01	49	*Kinross*	Loch Leven Sluice	4·93	125
,,	Scilly, Tresco Abbey	2·28	49	*Fife*	Leuchars Airfield	1·66	67
Glos.	Cirencester	1·42	42	*Perth*	Loch Dhu	7·46	74
Salop	Church Stretton	2·93	83	,,	Crieff, Strathearn Hyd.	5·89	131
,,	Cheswardine Hall	2·26	80	,,	Pitlochry, Fincastle	5·13	127
Staffs.	Malvern, Free Library	1·46	53	*Angus*	Montrose, Sunnyside	1·84	66
Worcs.	Birmingham, Edgbaston	1·63	61	*Aberd.*	Braemar	4·87	137
Warwick	Thornton Reservoir	1·80	67	,,	Dyce, Craibstone	1·53	45
Leics.	Boston, Skirbeck	1·28	60	,,	Fyvie Castle	1·48	43
Lincs.	Skegness, Marine Gdns.	1·55	70	*Moray*	Gordon Castle	4·95	184
,,	Mansfield, Carr Bank	2·33	80	*Nairn*	Nairn, Achareidh	4·65	227
Notts.	Buxton Terrace Slopes	7·13	126	*Inv's*	Loch Ness, Foyers		
Ches.	Bidston Observatory	3·76	142	,,	Glenquoich	24·24	165
Lancs.	Manchester, Whit. Park	4·93	152	,,	Fort William, Teviot	18·00	176
,,	Stonyhurst College	8·44	174	,,	Skye, Duntuilm	8·99	144
,,	Blackpool	5·00	153	*R. & C.*	Tain, Tarlogie House	5·67	200
Yorks.	Wakefield, Clarence Pk.	2·30	95	,,	Ullapool	7·78	128
,,	Hull, Pearson Park	2·64	110	,,	Applecross Gardens	10·64	165
,,	Felixkirk, Mt. St. John	2·28	95	,,	Achnashellach	17·07	180
,,	York Museum	1·91	85	,,	Stornoway Airfield	8·44	142
,,	Scarborough	2·58	108	*Suth.*	Loch More, Achfary	20·15	218
,,	Middlesbrough	2·13	110	*Caith.*	Wick Airfield	3·89	126
,,	Baldersdale, Hury Res.	7·13	192	*Shet.*	Lerwick Observatory	5·81	121
Nor'ld	Newcastle, Leazes Pk.	2·40	102	*Ferm.*	Crom Castle	6·06	146
,,	Bellingham, High Green	5·05	139	*Armagh*	Armagh Observatory	4·58	146
,,	Lilburn, Tower Gdns.	2·71	103	*Down*	Seaforde	3·12	100
Cumb.	Geltsdale	5·77	151	*Antrim*	Aldergrove Airfield	3·84	112
,,	Keswick, High Hill	10·66	160	,,	Ballymena, Harryville	5·09	102
,,	Ravenglass, The Grove	6·17	135	*Lon.*	Garvagh, Moneydig	5·92	148
Mon.	Abergavenny, Larchfield	2·13	48	,,	Londonderry, Creggan	7·04	161
Glam.	Ystalyfera, Wern House	8·19	98	*Tyrone*	Omagh, Edenfel	7·34	174

CLIMATOLOGICAL TABLE FOR THE BRITISH COMMONWEALTH, AUGUST 1949

Stations	Pressure		Temperatures							Relative humidity	Mean cloud amount	Precipitation			Bright Sunshine	
	Mean of day M.S.L.	Diff. from normal	Absolute Max.	Absolute Min.	Mean values Max.	Mean values Min.	Mean values ½ Max. and Min.	Mean values Diff. from normal	Mean values Wet bulb			Total	Diff. from normal	Days	Daily mean	Percentage of possible
	mb.	mb.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	oktas	in.	in.		hr.	%
London, Kew Observatory	1019·6	+4·7	83	47	73·8	56·1	64·9	+2·7	58·3	70	5·4	1·50	−0·74	8	7·3	50
Gibraltar	1016·5	0·0	99	67	86·5	73·2	79·9	+3·9	73·2	75	3·5	0·15	—	1	10·1	75
Malta	1016·8	+2·0	94	63	84·7	70·0	77·3	−1·8	70·6	56	1·0	0·05	—	1	11·9	88
St. Helena	1019·0	−0·9	66	52	63·1	53·9	58·5	+1·2	54·2	95	7·6	3·31	+0·71	20	—	—
Lungi, Sierra Leone	1013·4	—	85	71	81·6	73·1	77·3	—	73·9	92	7·2	32·05	—	28	2·9	23
Lagos, Nigeria ..	1013·6	+0·7	85	65	87·3	69·0	78·1	+0·2	74·6	88	7·3	3·13	—	17	3·6	29
Kaduna, Nigeria ..	1011·8	—	86	63	80·6	66·8	73·7	−0·5	69·9	86	7·4	10·82	−1·50	17	4·4	35
Chileka, Nyasaland	1019·8	−1·6	93	53	80·4	57·5	68·9	+1·7	58·0	58	1·5	0·00	−0·08	0	8·6	74
Lusaka, Rhodesia ..	1016·5	−1·2	93	45	83·0	54·6	68·8	+3·3	53·8	51	0·8	0·00	0·00	0	10·2	88
Salisbury, Rhodesia	1019·2	−1·5	88	39	76·7	48·3	62·5	+2·4	49·8	50	0·9	0·00	−0·10	0	9·6	84
Cape Town	1019·4	−0·9	73	42	63·8	49·5	56·7	+1·1	48·9	73	4·4	3·76	+0·39	16	—	—
Palmie fontein, S. Africa	1022·9	—	79	28	69·4	38·1	53·7	—	41·0	55	2·0	0·00	—	0	9·8	—
Mauritius	1019·3	−1·3	81	53	77·4	60·6	69·0	+0·5	63·3	72	4·2	1·00	−1·25	14	7·7	68
Calcutta, Alipore Obsy.	1000·7	0·0	94	75	89·7	79·5	84·6	+1·4	80·3	83	6·9	7·31	−6·07	23	3·8	29
Bombay	1004·6	−1·3	89	74	85·8	76·8	81·3	+0·5	77·5	86	6·4	15·22	+0·77	28	3·3	26
Madras	1005·2	−0·3	96	73	92·5	77·3	84·9	−1·1	76·0	77	6·9	5·21	+0·67	16	5·8	46
Colombo, Ceylon ..	1009·0	−0·3	87	73	85·2	77·7	81·5	+0·3	77·1	84	6·6	4·82	+1·58	19	6·1	50
Singapore	1009·7	+0·2	90	73	87·5	76·4	81·9	+0·8	76·6	79	6·5	3·19	−4·76	14	7·1	59
Hongkong	1006·1	+1·3	91	74	87·2	77·9	82·5	+0·4	78·3	87	—	14·07	−0·33	26	5·2	40
Sydney, N.S.W. ..	1023·2	+5·0	74	42	64·4	47·4	55·9	+0·9	48·9	71	3·7	5·06	+2·09	10	6·8	63
Melbourne	1022·1	+4·1	69	34	59·4	41·7	50·5	−0·5	44·6	67	5·0	0·99	−0·88	8	5·6	52
Adelaide	1022·6	+3·4	75	37	62·3	46·2	54·3	+0·3	48·2	61	4·0	1·51	−1·03	11	5·7	53
Perth, W. Australia	1017·2	−1·7	81	44	66·7	51·2	58·9	+2·9	55·4	75	5·0	6·67	+1·02	22	5·3	49
Coolgardie	1019·2	−0·1	81	35	67·9	44·9	56·4	+2·8	49·5	64	3·2	1·67	+0·68	7	—	—
Brisbane	1022·5	+3·3	78	42	70·2	49·2	59·7	−0·7	53·1	62	2·9	0·20	−1·81	4	7·8	70
Hobart, Tasmania																
Wellington, N.Z. ..	1014·6	−0·3	56	35	52·2	42·7	47·5	+0·2	45·0	80	5·0	4·42	−0·07	15	4·8	46
Suva, Fiji	1014·1	−0·1	84	63	78·1	68·8	73·5	−0·1	69·4	80	6·0	7·74	−0·55	17	4·5	39
Apia, Samoa ..	1013·2	+1·3	87	69	85·5	73·6	79·5	+1·0	76·0	78	4·4	6·28	+2·50	16	8·0	68
Kingston, Jamaica	1014·1	+0·6	94	72	90·2	74·5	82·3	+0·8	75·5	74	3·0	2·07	−1·48	9	8·4	66
Grenada, W. Indies	—	—	91	69	86·0	75·0	80·5	+0·8	76·0	83	5·0	6·23	−3·10	24	—	—
Toronto	1016·0	+0·6	99	50	82·8	63·4	73·1	+5·9	61·8	77	3·9	1·43	−1·36	7	9·5	68
Winnipeg	1014·0	+0·8	105	38	82·7	57·9	70·3	+6·5	58·3	86	4·3	2·27	+0·11	6	10·0	69
St. John, N.B. ..	1014·2	−1·1	87	47	73·6	56·8	65·2	+4·6	59·8	83	6·0	2·70	−1·16	14	7·5	53
Victoria, B.C. ..	1017·2	+0·3	80	48	68·1	51·2	59·7	0·0	52·4	92	6·4	0·84	+0·20	10	7·6	53